

What Industrial Designers Need to Know *Before* Reaching for a Pencil

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Design for Manufacturability

What is DFM?

Design for Manufacturability (aka. Design for Manufacturing or **DFM**) is the general principal of designing products in such a way that is easy to manufacture. DFM reflects the practice of designing or engineering a product to assist the manufacturing process in order to reduce its manufacturing costs.

The goal and main focus of DFM is to design a product that is easily and economically manufactured. It is important to consider approx. 70% of manufacturing costs of a product (material costs, material processing, and assembly) are determined by design decisions while production/manufacturing decisions (machine tool selection, etc.) are responsible for approx. 20%.

Design for Inspection(DFI) and Design for Assembly(DFA) are similar concepts that complement and work in collaboration with DFM to reduce product manufacturing costs and increase manufacturing practicality. An example of DFA might involve reducing the total number of components contained within an assembly thus reducing assembly time and saving labor cost. Although such methods and other principles support the role of DFM, they will not be discussed for purposes of this report. This report will specifically focus on the “cost of component” aspect within the DFM structure as highlighted in Fig 1.

Manufacturing?

Before focusing on the ‘cost of components’ aspect of DFM, it is important to first define manufacturing. For our purposes, manufacturing will be defined as the value added production of merchandise for use or sale utilizing labor and machine tools. Such production processes transform raw material(s) into finished goods which may be sold to other manufacturers for the production of other more complex products or sold wholesale directly to end users or consumers.

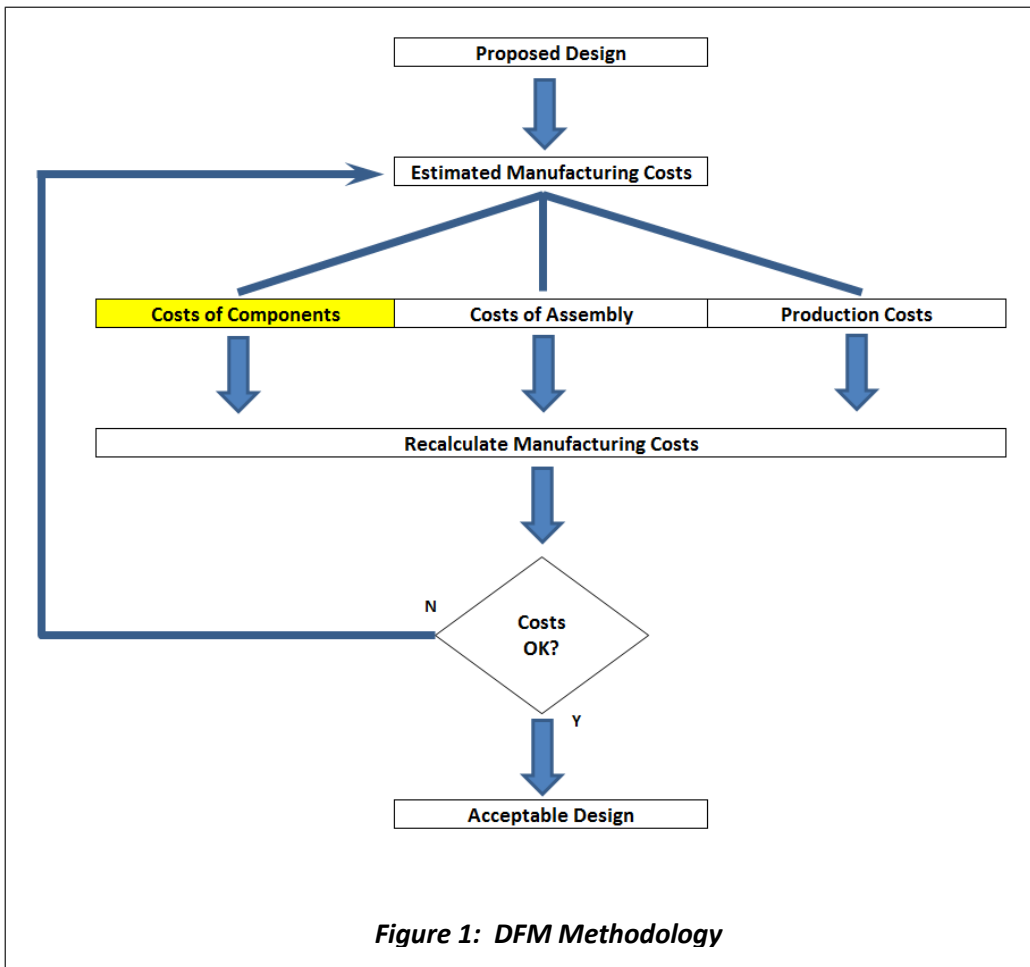


Figure 1: DFM Methodology

Costs of Components

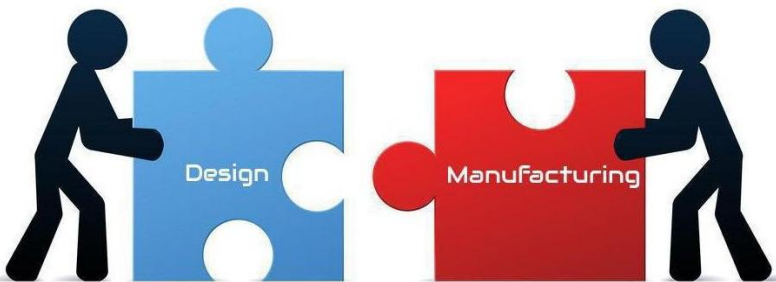
The process of DFM first begins with a product design proposal which includes functional/performance expectations and material specifications from which the product is to be manufactured. This could also be considered the “design phase” of the product. The outcome of the design phase results in a product design (sometimes dubbed a “prototype”). The design criteria of the product will determine which steps are needed through which raw materials are transformed into final products. It is during the design phase when it is most suitable (and the least expensive) to address potential problems.



Once the designer feels the product has been designed effectively, it can be approved by the appropriate parties and passed along for manufacturing. At this stage, the manufacturing engineering process will begin its support by applying focus to each individual step that will be required. Manufacturing engineering principles will determine the most appropriate process flow of material along with the most efficient methods of processing required at each step. It is here when manufacturing costs can be estimated.

Manufacturing Engineering

One main objective of manufacturing engineering is to keep manufacturing costs as low as possible while achieving and consistently maintaining product specifications. However, since the course of manufacturing engineering is established during the design phase via product design, it is important to understand the limited role of which it plays a part.



To further illustrate this concept, consider a product which requires a hole. The manufacturing engineer must determine how to make this hole become a reality. Engineering would determine which steps are needed (process flow) along with the method best suited for the hole-making process all of which are

dependent on the hole specifications (e.g. Are special fixtures/tools required? Does the hole require drilling? reaming?).

Many times, manufacturing engineers are not directly involved in the design phase and thus would be unaware if specific features or characteristics of a product could be revised to better suit manufacturing. Using the example above, the manufacturing engineer could be unaware of the holes purpose or design application. As a result, the manufacturing engineer would be unaware and unable to make recommendations for design improvements. Design improvements such as implementing a wider tolerance on the hole diameter (i.e. eliminating a reaming operation) &/or moving the hole to a new location in order to eliminate the need for separate fixturing and clamping operations would reducing manufacturing costs. This is

an example and the reason behind why approx. 70% of manufacturing costs are determined by product design criteria and not manufacturing decisions.

Cut Time to Cut Costs!

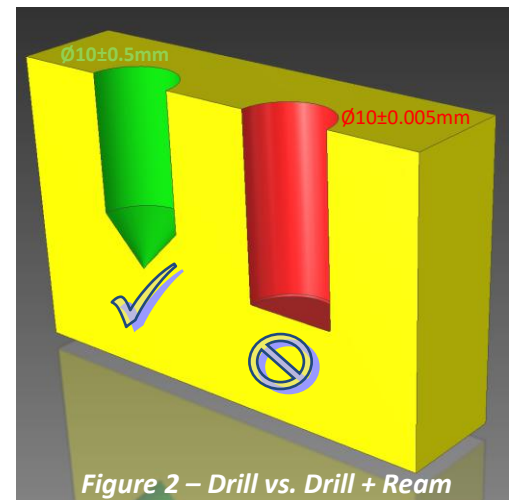
Since costs are driven by time, the design must minimize the time required to manufacture. For machining, this might involve activities such as:

- Reducing set-up time
- Reducing load/unload time
- Eliminating machined feature(s)
- Choosing a softer material (to reduce machining time)

There are many additional activities that can contribute to the manufacturing time required to complete a product. In general, the more complex the size and shape of the product, the more expensive it will be to manufacture.

A significant contributing factor to the cost of a machined component is the geometric tolerance to which features of a product must be held. Typically, the tighter the tolerance required, the higher the cost to manufacture the product. Tighter geometric tolerances also have a higher probability for rejection thus increasing potential for scrap and/or costs to rework (if reworking is an option). Wherever possible, designers should utilize creative methods to engineer products with wider tolerances that share the same performance characteristics as products with tighter tolerances.

An example of this concept can be seen in Figure 2. The figure reflects two holes that have the exact same function during application. However, different machining processes are required for each hole. The red hole requires a drilling and reaming operation to achieve the geometry (with tight tolerance) while the green hole requires only a drilling operation since a wider tolerance is allowed. These different machining processes result in different machining costs.



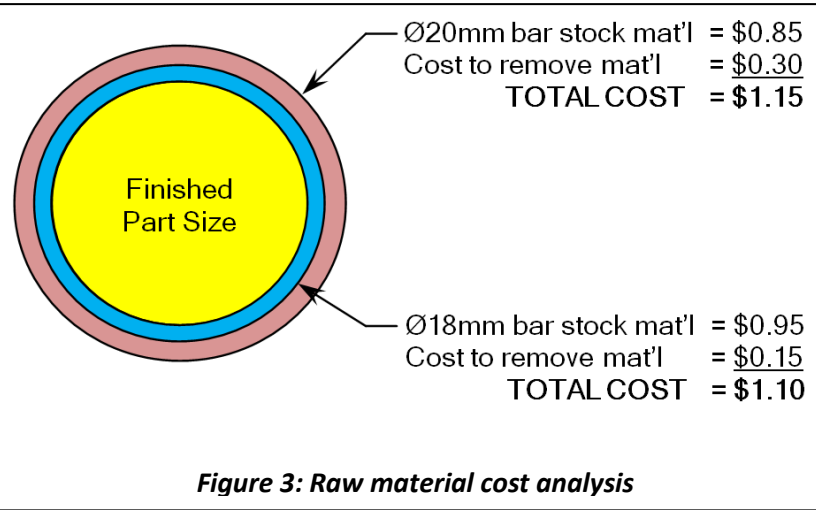
Machining is a subtractive process and the time required to remove material is a major contributing factor when determining machining costs. The quantity and type of feature(s) to be machined greatly affects the machining cost thus adds to the overall manufacturing costs. The volume and geometry of the material to be removed as well as the speed in which the tools can remove the material contribute to overall machining time (i.e. cutting time) and thus drive cost.

Cutting tools also play a significant role on cutting speed and thus drive cutting time. For example, when utilizing milling cutters, the strength and stiffness of the cutting tool factors the speed in which the cutting tool can be pushed through the material. This is determined, in part, by the length to diameter ratio. For example,

a shorter tool relative to its diameter can be fed faster through the material. A 3:1 ratio (L:D) or below is optimum.

Less can actually mean more....

In addition to cutting time, the type, size, and shape of the raw material directly influence stock removal



and/or fixturing of the workpiece for machining. Before procurement of raw material, collaboration should take place between manufacturing engineers and purchasing personnel to ensure the most cost effective solution before ordering. For example, Figure 3 shows the cost of ø20mm diameter bar material might be less expensive than ø18mm bar material since it is more common and readily available in the marketplace. However, the ø20mm bar would require removal of more material thus increasing machining time and costs to machine the product to finish size. In this

example, the lower cost of raw material does not guarantee the cost to manufacture the finished product will be lower.

Material handling is another area of focus that may influence manufacturing costs. At some point during the manufacturing process, a product or component may be positioned, oriented, and/or fixed into a machine or fixture for processing. The quantity and design of fixturing can have an effect on load/unload time which can directly influence manufacturing costs. Whenever possible, the designer should work to minimize

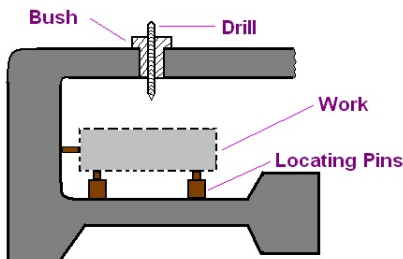


Figure 4: Jig

material handling and maximize common jigs and fixtures. Figures 4 and 5 show examples of jigs and fixtures.

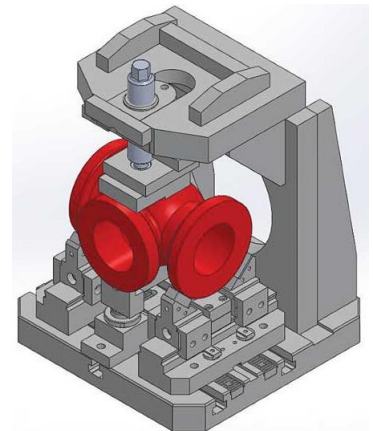


Figure 5: Fixture

The value of DFM?

DFM principles will allow a designer to present the most efficient design for the application while offering a cost effective solution for manufacturing. When merchandise is presented to the marketplace that meets performance characteristics while, at the same time, offering the manufacturer a lower cost option to produce the merchandise, value is formed. "Value" is what the customer is buying and, if a product can offer a better value than the competing merchandise, this value will translate into stronger product demand and higher sales growth for the manufacturer. This is a win-win scenario for the manufacturer as well as the consumer.